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THE RECOVERY OF POTASH AS A BY-PRODUCT IN THE CEMENT INDUSTRY.

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INTRODUCTION.

The present work is a continuation of an investigation that has been in progress in this laboratory for several years on the practicability of recovering potash from silicate rocks. Early in the investigation the conclusion was reached that owing to the small percentage of potash in commercial grades of any insoluble potash silicate, no process for recovering potash from such material can offer much promise of profitable application unless at the same time some product of value is recovered in addition to the potash. This principle now seems to be more or less generally recognized, and in the numerous patents that have appeared during the last two or three years on the subject of decomposing feldspar and other potash silicates specifications are given in most cases for the recovery, in addition to potash, of one or more of such various products as compounds of aluminum and of silicon, cement, raw material for the manufacture of glass or pottery, structural material, and pigment.

In a publication [1] prepared about five years ago, it was shown that when 1 part of feldspar and 3 parts of calcium carbonate were ignited about an hour at a temperature of 1,300–1,400°, the potash in the feldspar was completely volatilized and the clinker which remained was of such composition that the percentage of silica amounted to 3.2 times that of the alumina and the sum of these constituents amounted to exactly one-half the percentage of the lime present. The clinker obtained in this way, therefore, has a composition with respect to these constituents which falls within the limits required for Portland cement. It was observed also that when a quantity of calcium chloride equivalent to the alkalies in the feldspar was substituted for a part of the lime, volatilization took place in about half the time required when the ignition was made with lime alone; and that with the same mixture, on extending the time of ignition, almost complete decomposition of the feldspar could be effected at a temperature as low as 1,050°. Substitution of sodium chloride for calcium chloride gave approximately the same results.

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[1] Ross, William H., Circular No. 71, Bureau of Soils; Eighth Intern. Congress of Applied Chemistry, **15**, 217 (1912).

In a later publication [1] it was shown that when feldspar and lime in the proper proportion to make cement are digested with water at a steam pressure of 10 to 15 atmospheres, about 90 per cent of the potash in the feldspar passes into solution in the form of the hydroxide and the residue simply requires ignition for the manufacture of Portland-cement clinker. When the proportion of lime taken is reduced much below the limit stated, only partial decomposition of the feldspar results even at increased pressures, but by adding to such a mixture a quantity of a soluble calcium salt equivalent to the alkalies in the feldspar the amount of potash recovered may then be increased considerably.

The conclusion was drawn from these experiments that potash could be set free from feldspar by substituting the latter for clay in the manufacture of cement; that the potash would be volatilized to a greater or less extent and could be recovered in the flue dust; and that it should be possible to obtain raw materials of the proper composition to yield Portland-cement clinker on ignition.

In a series of experiments recently described by Anderson and Nestell,[2] cement mixtures from 10 different plants in this country and Japan were ignited in a way similar to that used in the ignition of the feldspar-lime mixtures. In every respect the results corresponded to those which were obtained in this laboratory by the ignition of feldspar with lime. Thus it was found that with different cement mixtures volatilization of the potash began at about 1,100°; at 1,200° the percentage of potash volatilized in a given time was different for the different mixtures, but when the temperature was increased to 1,300°, and maintained for 1 hour, almost complete volatilization resulted in every case. When heating an hour at 1,200° the addition of 5 per cent of sodium chloride to the raw material gave an increase in volatilization of the potash from 19 per cent to 66 per cent, while the use of calcium chloride was reported to be even more effective. The presence of sulphur dioxide in the furnace when the ignitions were made was found to have a retarding effect on the evolution of the potash.

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[1] Ross, W. H., J. Ind. Eng. Chem., **9**, 467 (1917).

[2] J. Ind. Eng. Chem., **9**, 253 (1917).

Since potash occurs in the form of feldspar or other silicates in the raw materials used in cement manufacture, it might be inferred from the experiments made on the ignition of feldspar mixtures and of cement materials that more or less complete volatilization of the potash would take place in the burning of cement.

It happens, however, that the clinkering zone of a rotary kiln constitutes only a comparatively short portion of its length, and while the time taken for the charge to pass through the kiln may vary from about 1½ to 2½ hours, depending on the length of the kiln, the time that the charge is subjected to a clinkering temperature does not exceed one-half hour. The length of a rotary kiln must also act disadvantageously on the escape of the potash. That some potash is volatilized in cement burning has long been known, and in the case of one plant a quantitative study of the amount lost in this way has been made by R. K. Meade[1] from analyses of the raw material fed into the kiln, the resulting clinker, and the coal used for burning. The results of three separate tests showed that the potash volatilized ranged from 46 to 52 per cent.

POTASH IN RAW MATERIALS AND LOSS THROUGH VOLATILIZATION IN CEMENT MANUFACTURE.

With a view to securing more extended information in this direction, an investigation was undertaken about five years ago to ascertain the percentage of potash occurring in the raw materials used in the different cement plants of this country and also the percentage of the total potash that is volatilized in each case. Representative samples of raw mix and ground clinker were collected from the different cement plants in the United States and in Canada, with a view to analyzing each sample for potash. With the data thus obtained, and knowing the ratio between the raw mix and the cement produced, and the output of the latter, it was thought possible to calculate for each plant the approximate quantity of potash that escapes daily from the kilns. After the work was partly completed it had to be abandoned for a time. A few months ago the problem was taken up again and entirely new samples were collected. The work now has been completed, with the results given in Table I.

This table shows that the potash occurring in the raw mix used by the different cement plants in this country varies from 0.20 to 1.16 per cent. The raw materials used in the mills of the Universal Portland Cement Co. consisting of blast-furnace slag and a high-grade limestone contain considerably less potash than the average for the other cement plants of the country.

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[1] Chem. Engineer, 2, 221 (1905).

TABLE I.—*Content of potash in raw materials and loss through volatilization in cement manufacture.*

State and company.	Location of plant.	Daily output.[a]	Raw mix required per barrel of cement.[b]	Potash in—		Potash in daily run of—		Daily loss of potash from kilns.	Proportion of total potash lost.	Potash lost per barrel of cement.	Estimated potash in flue dust.
				Raw mix.	Cement.	Raw mix.	Cement.				
Alabama:		*Barrels.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
Coosa Portland Cement Co. [c] DC.	Ragland	3,000	[d] 608	0.68	0.59	12,403	6,726	5,677	45.8	1.89	7.8
Standard Portland Cement Co. DC.	Leeds	2,000	592	.73	.69	8,643	5,244	3,399	39.3	1.70	7.2
California:											
Cowell Portland Cement Co. DO.	Cowell	4,000	608	.59	.55	14,349	8,360	5,989	41.7	1.50	6.2
Golden State Portland Cement Co. DO.	Oro Grande	650	648	.80	.44	3,370	1,087	2,283	67.7	3.51	13.5
Monolith Portland Cement Co. DO.	Monolith	1,200	600	.64	.32	4,608	1,459	3,149	68.3	2.62	10.9
Pacific Portland Cement Co., Consolidated. DO.	Cement	6,000	585	.50	.50	17,550	11,400	6,150	35.0	1.03	4.4
Riverside Portland Cement Co. DO.	Riverside	5,500	[e] 594	[e] .50	[e] .22	16,335	4,598	11,737	71.9	2.13	9.0
Santa Cruz Portland Cement Co. DO.	Davenport	8,000	658	.76	.33	40,006	10,032	29,974	74.9	3.75	14.2
Standard Portland Cement Corporation DO.	Napa Junction	2,500	650	.47	.33	7,638	3,135	4,503	59.0	1.80	6.9
Colorado:											
Colorado Portland Cement Co. DC.	Portland	3,000	633	.78	.56	14,812	6,384	8,428	56.9	2.81	11.1
United States Portland Cement Co. DC.	Concrete	1,500	633	.72	.42	6,836	2,394	4,442	65.0	2.96	11.7
Georgia:											
Southern States Portland Cement Co. DC.	Rockmart	1,500	600	.98	.73	8,820	4,161	4,659	52.8	3.11	12.9
Illinois:											
Lehigh Portland Cement Co. DC.	Oglesby	5,000	620	.70	.71	21,700	13,490	8,210	37.8	1.64	6.6
German-American Portland Cement Co. DC.	La Salle	6,000	620	.43	.53	15,996	12,084	3,912	24.5	.65	2.6
Marquette Cement Manufacturing Co. DC.	do	7,000	615	.70	.63	30,135	16,758	13,377	44.4	1.91	7.8
The Sandusky Cement Co. DC.	Dixon	3,500	608	.88	.59	18,726	7,847	10,879	58.1	3.11	12.8
Indiana:											
Lehigh Portland Cement Co. DC.	Mitchell	[b] 6,600	[d] 608	.79	.71	31,701	17,807	13,894	43.8	2.11	8.7
Louisville Cement Co. DC.	Speeds	3,000	600	.67	.65	12,060	7,410	4,650	38.6	1.55	6.5
The Sandusky Cement Co. WC.	Syracuse	2,000	608	.77	.79	9,363	6,004	3,359	35.9	1.68	13.8
Universal Cement Co. DC.											
Mill No. 3	Buffington	6,000	546	.30	.29	9,828	6,612	3,216	32.7	.54	2.5
Mill No. 4	do	7,000	554	.29	.26	11,246	6,916	4,330	38.5	.62	2.8
Mill No. 6	do	13,000	530	.29	.28	19,981	13,832	6,149	30.8	.47	2.2
Iowa:											
Hawkeye Portland Cement Co. WC.	Des Moines	3,500	625	.58	.39	12,688	5,187	7,501	59.1	2.14	17.1
Lehigh Portland Cement Co. DC.	Mason City	[b] 5,083	622	1.00	.63	31,600	12,169	19,431	61.5	3.82	15.3
Northwestern States Portland Cement Co. DC.	do	6,000	600	1.08	.99	38,880	23,572	16,308	41.9	2.72	10.8
Kansas:											
Ash Grove Portland Cement Co. WGCO.	Chanute	3,000	638	.55	.50	10,527	5,700	4,827	45.9	1.61	12.6
Bonner Portland Cement Co. DC.	Bonner Springs	1,500	601	.72	.67	6,484	3,876	2,608	40.2	1.74	7.2
Iola Portland Cement Co. WGCO.	Iola	4,000	646	.58	.60	14,987	9,120	5,867	39.2	1.47	11.4
Monarch Cement Co. DCO.	Humboldt	3,000	[d] 608	.44	.34	8,026	3,876	4,150	51.7	1.38	5.7
The Western States Portland Cement Co. DGO.	Independence	3,500	640	.43	.27	9,632	3,591	6,041	62.7	1.73	6.7

Kentucky:											
Kosmos Portland Cement Co.......DC..	Kosmosdale.......	3,000	600	.75	.57	13,500	6,498	7,002	51.9	2.33	9.7
Maryland:											
Security Cement & Lime Co.......DC..	Security..........	3,000	600	b 1.10	b 1.05	19,800	11,970	7,830	39.5	2.61	10.9
Tidewater Portland Cement Co.......DC..	Union Bridge.....	4,000	615	.71	.46	17,466	6,992	10,474	60.0	2.62	10.6
Michigan:											
Aetna Portland Cement Co.......WC..	Fenton..........	1,800	608	.72	.69	7,880	4,720	3,160	40.1	1.80	14.5
Burt Portland Cement Co.......DC..	Bellevue.........	2,000	608	.43	.35	5,229	2,660	2,569	49.1	1.28	5.3
Huron Portland Cement Co.......DC..	Alpena...........	5,000	630	.89	.80	28,035	15,200	12,835	45.8	2.57	10.2
Michigan Portland Cement Co.......WC..	Chelsea..........	1,200	635	.65	.60	4,953	2,736	2,217	44.7	1.85	14.5
New Egyptian Portland Cement Co.......WC..	Fenton..........	1,800	597	.72	.77	7,737	5,267	2,470	31.9	1.37	11.4
Peerless Portland Cement Co.......WC..	Union City.......	1,800	572	.56	.51	5,766	3,488	2,278	39.4	1.26	11.1
Peninsular Portland Cement Co.......WC..	Cement City......	1,800	627	.71	.87	8,013	5,951	2,062	25.7	1.15	9.1
Wyandotte Portland Cement Co.......DC..	Wyandotte.......	1,000	540	.81	.77	4,374	2,926	1,448	33.1	1.45	6.7
Minnesota:											
Universal Portland Cement Co.......DC..	Duluth..........	4,000	614	.20	.23	4,912	3,496	1,416	28.8	.35	1.4
Missouri:											
Atlas Portland Cement Co.......DC..	Hannibal.........	b 7,000	600	b .95	b .92	39,900	24,472	15,428	38.7	2.20	9.2
Cape Girardeau Portland Cement Co.......DC..	Cape Girardeau...	1,800	640	.66	.51	7,603	3,488	4,115	54.1	2.28	8.9
Continental Portland Cement Co.......DC..	Continental.......	2,500	642	.42	.38	6,741	3,610	3,131	46.4	1.25	4.9
Union Sand & Material Co.......DC..	Prospect Hill.....	3,500	600	.80	.77	16,800	10,241	6,559	39.0	1.87	7.8
Do..........	Sugar Creek.......	2,500	600	.74	.85	11,100	8,075	3,025	27.2	1.21	5.0
Montana:											
Three Forks Portland Cement Co.......DC..	Trident	2,250	d 608	1.16	1.04	15,869	8,892	6,977	44.0	3.10	12.8
Nebraska:											
Nebraska Portland Cement Co.......DC..	Superior	2,500	625	.65	.72	10,156	6,840	3,316	32.7	1.33	5.3
New Jersey:											
Alpha Portland Cement Co.......DC..	Alpha	b 4,500	625	.93	.89	26,156	15,219	10,937	41.5	2.43	9.7
Edison Portland Cement Co.......DC..	New Village	8,000	640	.69	.70	35,328	21,280	14,048	39.8	1.76	6.9
Vulcanite Portland Cement Co.......DC..	Vulcanite	6,000	640	.58	.58	22,272	13,224	9,048	40.6	1.51	5.9
New York:											
Acme Cement Corporation.......WC..	Acme	2,500	d 608	.51	.51	7,752	4,845	2,907	37.5	1.16	9.6
Alpha Portland Cement Co.......DC..	Cementon	b 3,000	625	b .82	b .63	15,375	7,182	8,193	53.2	2.73	10.9
Alsen's American Portland Cement Works..DC..	Alsen	3,000	d 608	.56	.61	10,214	6,954	3,260	31.9	1.09	4.5
Atlas Portland Cement Co.......DC..	Hudson	b 5,000	600	b .66	b .74	19,800	14,060	5,740	29.0	1.15	4.8
Cayuga Cement Corporation.......DC..	Portland Point ...	2,000	619	.80	.71	9,910	5,396	4,514	45.6	2.26	9.1
Glens Falls Portland Cement Co.......DC..	Glens Falls	2,000	602	.88	.81	10,596	6,156	4,439	41.9	2.22	9.2
Helderberg Cement Co.......WC..	Howes Cove	2,000	597	.61	.61	7,283	4,636	2,647	36.2	1.32	11.1
Knickerbocker Portland Cement Co.......WC..	Hudson	4,000	593	.81	.78	19,206	11,856	7,350	38.3	1.84	15.4
Ohio:											
Castalia Portland Cement Co.......WC..	Castalia..........	2,000	684	.66	.11	9,029	836	8,193	90.7	4.10	30.0
Diamond Portland Cement Co.......DC..	Middle Branch....	1,500	630	.67	.67	6,332	3,819	2,513	39.6	1.67	6.6
Ironton Portland Cement Co.......DG..	Ironton...........	1,800	600	.94	.43	10,152	2,941	7,211	71.0	4.01	16.7
The Sandusky Cement Co.......WC..	Bay Bridge.......	2,000	608	.60	.66	7,296	5,016	2,280	31.3	1.14	9.4
Superior Portland Cement Co.......DC..	Superior..........	2,000	694	.59	.44	8,189	3,344	4,845	59.2	2.42	8.7

[a] Directory of Cement, Gypsum, and Lime Manufacturers, unless otherwise indicated.
[b] Information supplied by company, unless otherwise indicated.
[c] D, dry process; W, wet process; C, coal used for burning; G, gas used for burning; O, oil used for burning.
[d] Assumed.
[e] Information supplied by the Western Precipitation Co.

TABLE I.—*Content of potash in raw materials and loss through volatilization in cement manufacture*—Continued.

State and company.	Location of plant.	Daily output.[a]	Raw mix required per barrel of cement.[b]	Potash in—		Potash in daily run of—		Daily loss of potash from kilns.	Proportion of total potash lost.	Potash lost per barrel of cement.	Estimated potash in flue dust.
				Raw mix.	Cement.	Raw mix.	Cement.				
		Barrels.	Pounds.	Per cent.	Per cent.	Pounds.	Pounds.	Pounds.	Per cent.	Pounds.	Per cent.
Oklahoma:											
Dewey Portland Cement Co. DC	Dewey	3,000	600	0.54	0.47	9,720	5,358	4,362	44.9	1.45	6.1
Oklahoma Portland Cement Co. DG	Ada	3,000	606	.95	.92	17,271	10,488	6,783	39.3	2.24	9.2
Pennsylvania:											
Allentown Portland Cement Co. DC	Evansville	2,500	[c] 608	[d] .46	[d] .39	6,992	3,705	3,287	47.0	1.31	5.4
Alpha Portland Cement Co. DC	Martins Creek	[d] 10,000	625	.92	.77	57,500	29,260	28,240	49.1	2.82	11.3
Atlas Portland Cement Co. DC	Northampton	[d] 16,000	600	[d] .74	[d] .71	71,040	43,168	27,872	39.2	1.74	7.3
Bath Portland Cement Co. DC	Bath	3,000	640	.81	.83	15,552	9,462	6,090	39.2	2.03	7.9
Coplay Cement Manufacturing Co. DC	Coplay	2,000	680	.54	.45	7,346	3,420	3,926	53.4	1.96	7.2
Do	Saylors	3,500	680	.61	.46	14,522	6,118	8,404	57.9	2.40	8.8
Dexter Portland Cement Co. DC	Nazareth	2,600	[c] 608	[d] .85	[d] .77	13,437	7,608	5,829	43.4	2.24	9.2
Giant Portland Cement Co. DC	Egypt	[d] 5,000	640	.77	.59	24,640	11,210	13,430	54.5	2.69	10.5
Lawrence Portland Cement Co. DGC	Siegfried	4,600	610	1.01	.88	28,340	15,382	12,958	45.7	2.82	11.5
Lehigh Portland Cement Co. DC	Fogelsville	[d] 4,657	608	.71	.47	20,103	8,317	11,786	58.6	2.53	10.4
Do	New Castle	[d] 5,380	621	.78	.65	26,072	13,288	12,784	49.0	2.38	9.6
Do	Ormrod	[d] 8,900	606	.63	.38	33,978	12,852	21,126	62.0	2.37	9.8
Do	West Coplay	[d] 2,826	604	.63	.53	10,757	5,691	5,066	47.1	1.79	7.4
Nazareth Cement Co. DC	Nazareth	4,000	620	.84	.64	20,832	9,728	11,104	53.3	2.78	11.2
Penn-Allen Cement Co. DC	Penn-Allen	2,100	600	.75	.71	9,450	5,666	3,784	40.0	1.80	7.5
Pennsylvania Cement Co. DC	Bath	3,000	610	.78	.69	14,274	7,866	6,408	44.9	2.14	8.8
Phoenix Portland Cement Co. DC	Nazareth	2,500	[c] 608	.79	.73	12,008	6,935	5,073	42.3	2.03	8.4
The Sandusky Cement Co. DG	York	400	608	.50	.27	1,216	410	806	66.3	2.02	8.3
Universal Portland Cement Co. DC	Universal	10,000	581	.36	.36	20,916	13,680	7,236	34.6	.72	3.1
Whitehall Cement Manufacturing Co. DC	Cementon	4,200	580	.77	.58	18,741	9,257	9,484	50.6	2.26	9.7
Tennessee:											
Clinchfield Portland Cement Corporation DC	Kingsport	4,000	630	.77	.63	19,404	9,576	9,828	50.6	2.46	9.8
Dixie Portland Cement Co. WC	Richard City	4,000	615	.71	.51	17,466	7,752	9,714	55.6	2.43	19.8
Texas:											
San Antonio Portland Cement Co. DO	Cementville	1,400	633	.47	.30	4,165	1,596	2,569	61.7	1.84	7.3
Southwestern Portland Cement Co. DC	El Paso	1,500	585	.40	.38	3,510	2,166	1,344	38.3	.90	3.8
Texas Portland Cement Co. WO	Cement	4,000	610	.90	.81	21,960	12,312	9,648	43.9	2.41	19.8
Trinity Portland Cement Co. DOG	Eagle Ford	3,000	630	.75	.76	14,175	8,664	5,511	38.9	1.83	7.3
Utah:											
Ogden Portland Cement Co. WC	Bakers	700	633	.73	.05	3,237	133	3,104	95.9	4.43	35.1
Portland Cement Co., of Utah DC	Salt Lake City	1,200	644	.94	.24	7,264	1,094	6,170	84.9	5.14	20.1
Union Portland Cement Co. DC	Devil's Slide	2,500	[c] 608	.79	.59	12,008	5,605	6,403	53.3	2.56	10.5
Virginia:											
Giant Portland Cement Co. WC	Norfolk	2,000	581	.29	.28	3,372	2,128	1,244	36.9	.62	5.4
Lehigh Portland Cement Co. DC	Fordwick	[d] 3,300	612	1.03	.89	20,802	11,161	9,641	46.3	2.92	11.9

Washington:										
International Portland Cement Co., Ltd....DC	Irvin	1,800	627	.78	.76	8,803	5,198	3,605	40.9	2.00	8.0
Lehigh Portland Cement Co....DC	Metalline Falls	d 1,800	608	1.00	.99	10,944	6,772	4,172	38.1	2.32	9.5
Olympic Portland Cement Co., Ltd....WO	Bellingham	2,000	580	.56	.51	6,496	3,876	2,620	40.3	1.31	11.2
Superior Portland Cement Co....DO	Concrete	2,500	c 608	.20	.21	3,040	1,995	1,045	34.4	.42	1.7
Washington Portland Cement Co....DO	...do	2,200	608	.39	.26	5,217	2,174	3,043	58.3	1.38	5.7
West Virginia:											
Alpha Portland Cement Co....DCG	Manheim	d 2,800	625	.74	.91	12,950	9,682	3,268	25.2	1.16	4.7
Canada:											
Alberta—											
Canada Cement Co., Ltd....DC	Exshaw	3,000	612	.70	.69	12,852	7,866	4,986	38.8	1.66	6.8
British Columbia—											
Associated Cement Co., Ltd....WO	Bamberton	2,000	608	.50	.47	5,600	3,290	2,310	41.2	1.15	9.4
Manitoba—											
Canada Cement Co., Ltd....DC	Winnipeg	4,000	646	.75	.76	19,380	11,552	7,828	40.4	1.96	7.6
Ontario—											
Canada Cement Co., Ltd....DC	Belleville	2,800	585	1.04	.83	17,035	8,831	8,204	48.2	2.93	12.5
Canada Cement Co., Ltd....DGC	Port Colborne	3,000	634	.79	.61	15,026	6,954	8,072	53.7	2.69	10.6
Hanover Portland Cement Co., Ltd....WC	Hanover	700	608	1.02	1.02	4,341	2,713	1,628	37.5	2.32	19.0
Ontario Portland Cement Co., Ltd....WC	Blue Lake	750	c 608	.68	.40	3,101	1,140	1,961	63.2	2.61	21.5
St. Mary's Cement, Ltd....WC	St. Mary's	1,500	608	.89	.95	8,117	5,415	2,702	33.3	1.80	14.7
Quebec—											
Canada Cement Co., Ltd....DC	Montreal	12,000	608	.81	.85	59,098	38,760	20,338	34.4	1.69	7.0

a Directory of Cement, Gypsum, and Lime Manufacturers, unless otherwise indicated.
b Information supplied by company, unless otherwise indicated.
c Assumed.
d Information supplied by company.

NOTE.—Checks on the analyses of a number of these samples were made by J. A. Cullen.

In a communication received from the manager of one of the large cement plants in the Lehigh Valley district the statement was made that the raw cement material used in this district contains less than 0.3 per cent. The samples analyzed in these experiments, however, indicate that in no case does the raw mix used in the plants of this district run as low as 0.3 per cent, but that some of these plants make use of cement material almost as rich in potash as may be found in any cement plant in the country. In general it may be stated, however, that high potash-bearing raw material is not characteristic of any particular part of the country.

The values given in Table I for the potash contained in the daily production of cement were obtained by multiplying the output in barrels by the weight of one barrel (380 pounds) and by the percentage of potash in the cement as found by analysis. To obtain the corresponding values for the potash in the daily run of raw mix, the output of cement expressed in barrels was multiplied by the weight of raw mix required per barrel of cement and then by the percentage of potash in the raw mix. The difference between the two values as thus determined represents the potash that escapes daily from the kilns. As shown in the table, this varies in different plants from 0.35 to 5.14 pounds of K_2O per barrel of cement produced. The average for all the plants listed in the table when consideration is taken of the variation in output of cement of the different plants amounts to 1.93 pounds[1] per barrel of cement.

Omitting the plants of the Universal Portland Cement Co., the corresponding average for the remainder of the 99 plants of this country from which samples were received amounts to 2.09 pounds. The average for the nine Canadian plants is 1.95 pounds. The total number of plants in this country from which samples were received is only four less than the total number which operated in 1915[2] and nine less than the total number said to be in operation in 1916.

The average daily output of cement from the individual plants in many cases is considered confidential information. In Table I, therefore, it was necessary to give values for the output of the individual plants which represent capacities rather than actual production. The total annual production as obtained from these values is consequently much in excess of that which is known to have been produced in any one year. The values given for the potash lost per barrel of cement are, however, independent of the output. If, therefore, the average annual production of Portland cement in this country be now taken in round numbers as 90,000,000 barrels[1] and if the same average conditions be assumed to prevail in the few plants from which no samples were received as was found on an average for all other plants, then it may be estimated that the total potash (K_2O) escaping from all the cement plants in this country as at present operated amounts to 86,850 tons annually.

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[1] In making this calculation no account was taken of the potash in the coal, which at most would not amount to more than a few tenths of a pound per barrel of cement. Any potash present, however, would tend to increase the value given for the amount of potash volatilized. Cf. R. K. Meade, Portland Cement, 2d ed., p. 179.

[2] Burchard, E. F., Cement in 1915. Mineral resources of the U. S., 1915, Part II, p. 195.

The process at present most generally considered in connection with the recovery of the potash that escapes from cement kilns is electrical precipitation. The extent to which the dust may be recovered in this way is dependent, assuming proper installation, on the voltage used and the linear velocity with which the gases pass through the treater pipes. The volume of gases treated being constant, the degree of precipitation of the dust will be dependent on the extent of the installation. With present installations a recovery of approximately 99 per cent[2] of the dust has been obtained. It happens, however, that the finest portion of the dust escaping from any cement plant contains relatively the highest percentage of potash, and a 99 per cent recovery of the dust represents a somewhat less efficient recovery of the potash.

In the plant of the Security Cement and Lime Co., where the Cottrell process of electrical precipitation has been installed, it is found that under normal working conditions, and with a daily output of 2,500 barrels, the dust collected in the kiln stacks amounts to 16,000 pounds and in the treaters 45,000 pounds every 24 hours. The former contains on an average 4.5 per cent potash, and the latter, as analyzed in this laboratory, 11.4 per cent, making a total of 5,850 pounds of potash recovered daily. As shown in Table I, the potash lost from the kilns during the same period amounts to 6,525 pounds. On this basis of calculation the potash recovery in this plant amounts to 90 per cent of the total. If this value be accepted as the efficiency of recovery of the potash in the most economic installations, then the total recoverable potash in the cement plants of this country under present working conditions amounts to 78,165 tons annually.

The potassium compounds occurring in cement dust may be divided into three groups, as follows: (1) Those which are readily soluble in water; (2) those which are slowly soluble; and (3) those which are insoluble.

The insoluble potash represents the combinations occurring in the original silicates of the raw mix carried over mechanically in the dust before being subjected to a sufficiently high temperature to bring about decomposition. The form of combination which is slowly soluble in water is supposed to be due to a recombination of the volatilized potash with the silicates in the dust. In some plants where coal is used for burning the extent to which the potash occurs in this "recombined" form may be considerable, while in certain other plants where oil is used for fuel this combination of the potash occurs in comparatively small amount. In Table II the percentages of the different forms of potash occurring in a dust from a plant which uses oil for fuel and also from one which uses coal are given:

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[1] Burchard, E. F. Loc. cit.

[2] Schmidt, W. A., Paper presented at the meeting of the American Institute of Mining Engineers, Globe, Ariz., Sept. 21, 1916.

TABLE II.—*Percentages of the different combinations of potash in flue-dust samples from different sources.*

Combination.	Cement dust from—	
	Riverside Portland Cement Co.	Security Cement and Lime Co.
	Per cent.	*Per cent.*
Acid-insoluble potash, K_2O	0.2	0.5
Slowly soluble potash	.7	4.1
Water-soluble potash	9.8	6.8
Total	10.7	11.4

The determinations of the soluble potash in these samples were made by boiling 10 grams of the sample in 500 cubic centimeters of water for one-half hour as directed in the Methods of the Association of Official Agricultural Chemists. The insoluble potash was assumed to be that portion of the total potash which remained insoluble after boiling in a 5 per cent solution of hydrochloric acid. The difference between the total potash and the sum of the soluble and insoluble portions was then taken as the proportion of the potash which is slowly soluble in water.

In a previous publication it was shown, as already stated, that the greater part of the potash in feldspar may be made to pass into solution by digesting with lime under a steam pressure of 10 to 15 atmospheres. In cement dust as it escapes from the kilns the slowly soluble and the insoluble potash already are associated with a considerable percentage of free lime and consequently it was thought that the greater part of these constituents might be recovered in soluble form by digesting the dust with steam alone under pressure. This has been found to be the case, and with the Security cement dust it has been found possible to recover in this way in soluble form and with little increase in pressure upward of 95 per cent of the total potash present. If it be assumed, therefore, that it would be practicable to recover, or render available, say, 95 per cent[1] of the potash in the recoverable dust of cement plants, then the recoverable and available potash escaping from the cement plants of this country amounts approximately to 75,000 tons annually. If, however, the dust from all plants losing less than 1 pound of potash per barrel of cement be considered as too low grade for use as a source of fertilizer material and the figures from such plants be omitted in the calculations, then the value for the available recoverable potash in the cement industry of this country as normally operated becomes 71,000 tons annually.

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[1] In the case of coal-fired plants it may not be possible, with present commercial apparatus, to render soluble as much as 95 per cent of the collected potash, but there is no doubt that as details of commercial apparatus are perfected this value will represent a fair average for the different plants of the country.

PERCENTAGE OF VOLATILIZATION OF POTASH IN CEMENT PLANTS.

As shown in Table I, the proportion of the total potash (K_2O) that is volatilized varies in different plants from 24.5 to 95.9 per cent. The lowest values were obtained for plants widely separated from one another. In the Hudson River district the percentage volatilization varies from about 30 per cent to 45 per cent, and in the Lehigh Valley district from about 40 per cent to 60 per cent. In plants situated in the northern Central States considerable variation was noted. The highest values were found for plants located in southern California, and in Colorado and Utah.

It may be pointed out that as much variation occurs in the percentage of potash volatilized from plants using oil as from those using coal. It is also to be noted that the average percentage volatilization (46 per cent) in plants using the wet process is almost as great as that (47 per cent) in plants using the dry process, and in fact the highest percentage volatilizations, 95.9 per cent and 90.7 per cent, were found for plants using the wet process. This result is contrary to what seems to have been the general opinion among cement manufacturers, as indicated by the following excerpts from communications received from two firms using the wet process: (*a*) "Our plant is a wet-process plant, and the amount of potash which goes up in the air we figure is infinitesimal as compared with plants using the dry process of manufacture." (*b*) "In our manufacture of Portland cement we use the wet method of grinding our raw materials and in a short time I believe the entire cement industry will depart from the present dry method and adopt the wet method so that there will be no more precipitation of volatilized potash in our smokestacks."

That a smaller proportion of dust should be carried over mechanically in the wet-process plants is to be expected, and the loss of dust should be particularly reduced in those plants in which the kilns are provided with cross-partition plates which continuously raise the wet slurry and allow it to fall again as a spray. Judging from the observations that have been made in other industries, however, it is not so apparent that the wet process should retard very greatly the escape from the kilns of that portion of the potash which actually is volatilized.

Thus, R. J. Wysor[1] has shown in an investigation on the escape of potash from blast furnaces that the specially designed tower spray washers used for purifying the gas from the blast furnace are only moderately efficient in freeing the gas from the finest dust particles, and that much of the water-soluble alkalies remains in the gas current after leaving the washers. This result is explained on the ground that the particles of fume are in such an exceedingly fine state of division that they escape contact with the relatively large drops of water.

Experiments to show the effect of variations in burning on the volatilization of potash have been made recently at the plant of the Security Cement and Lime Co. It was found that as the burning conditions were varied from normal to such a temperature as to give overburned clinker, the percentage volatilization of the potash increased from 31.6 per cent to 42.6 per cent.[2]

A similar result was obtained also in this laboratory in the analysis of seven cement samples furnished us by the Tidewater Portland Cement Co. The samples were collected successively as the burning was raised from a temperature giving a very soft clinker to that sufficient to make a very hard clinker. Corresponding samples of raw mix were collected at the same time, giving a composite sample which analyzed 0.71 per cent potash. The results obtained in the analysis of the cement samples are shown in Table III.

TABLE III.—*Effect of variable burning on the liberation of potash in cement kilns.*

Sample.	Potash in clinker.	Proportion of total potash volatilized.	Sample.	Potash in clinker.	Proportion of total potash volatilized.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
No. 1 [a]	0.69	40.0	No. 5	0.51	55.6
No. 2	.70	39.1	No. 6	.44	61.7
No. 3	.58	49.5	No. 7 [b]	.48	58.4
No. 4	.54	50.7			

[a] Very soft. [b] Very hard.

These results show that the potash volatilized increases with the temperature of burning, but the increase apparently is not sufficient to attribute the great variation in the potash volatilized in different plants entirely to differences in the temperature of burning.

That it is possible also to bring about by chemical means an increase in the amount of potash volatilized has been demonstrated recently at the plant of the Security Cement and Lime Co. This is effected by adding ordinary salt both to the raw mix and to the coal used for fuel, and in such quantity that the total added amounts to 1 per cent of the raw mix. The salt is added in the solid state and is brought into intimate mixture with the raw mix and coal by being ground with these materials. The quality of the resulting cement is in no sense impaired by the addition of the salt, for it is found that the total alkalies in the clinker when salt is added to the charge are actually less than when no salt is added, due to the fact that the percentage of the potash is reduced more than the percentage of the soda is increased. By this treatment the percentage of the potash volatilized, which at this plant normally runs about 38 per cent, is increased to about 65 per cent. Assuming that this percentage volatilization (65 per cent) could be attained by chemical or other means in all plants where a lower volatilization normally prevails, then it may be estimated that the recoverable available potash in the cement plants of this country would be increased from 71,000 tons to 101,000 tons annually. In making this calculation it is assumed as before that 90 per cent of the total potash volatilized is recovered, but that the additional recoverable potash is all available.

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[1] Bul. Am. Inst. Mining Engineers, 121, 1 (1917).

[2] Anderson and Nestell. Loc. cit.

Other processes that have been proposed for bringing about an increase in the volatilization of the potash involve treatment with such reagents as calcium chloride,[1] calcium fluoride,[2] sulphur dioxide,[3] and steam.[3]

The method of increasing the volatilization of the potash by use of calcium fluoride as proposed by Huber and Reath [4] has been tested on a commercial scale and is worthy of special mention. In this process the fluorine compound is first added to the argillaceous component of the cement material in the form of fluorite and in quantity approximately equivalent to the potassium present. This material is then properly proportioned with limestone to give normal Portland-cement raw mixture and burned in a rotary kiln in the usual way. Volatilization of the potash under these conditions largely takes place in the form of the fluoride, which, as it escapes from the kilns, becomes associated with the salts of calcium carried over mechanically in the dust. It thus happens that when the dust is leached with hot water the potash passes into solution as sulphate or carbonate, while the fluorine remains behind as insoluble calcium fluoride. On using the residue as cement material the same fluorine is fed into the furnace again and may thus be repeatedly used in bringing about increased volatilization of the potash.

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[1] Herstein, B., J. Ind. Eng. Chem., 3, 426 (1911); Ross, William H., Circ. No. 71, Bureau of Soils; Brown, H. E., U. S. Patents Nos. 1,123,841 and 1,124,238; Ellis, C., U. S. Patent No. 1,186,522; Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

[2] Ellis, C., U. S. Patent No. 1,186,522; Huber, A. W., and Reath, F. F., U. S. Patents Nos. 1,194,344 and 1,219,315; Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

[3] Spackman, H. S., and Conwell, E. L., U. S. Patent No. 1,202,327.

[4] Loc. cit.

RELIABILITY OF THE RESULTS OBTAINED.

All potash determinations were made by the J. Lawrence Smith method, modified by converting the chlorides into sulphates to insure against loss of potash on driving off ammonium salts and then proceeding as in determining water-soluble potash according to the Methods of the Association of Official Agricultural Chemists. The duplicate determinations in every case were made by different persons and each percentage value for potash in raw mix and in cement thus represents the mean of the results found by two analysts. No percentage values of which a mean was taken differed by more than 0.12, and most differences in results were well within this limit.

When requesting samples for analysis from the different plants attention was called to the importance of selecting cement and raw-mix samples which correspond as closely as possible with one another, and which were representative of normal working conditions. This request seems to have been observed by most if not all plants, and judging by letters received it appears that a great deal of care was taken by many cement officials in collecting the samples. Each sample selected for analysis was reduced to a fineness of 175 mesh by grinding the portion which failed to pass through the screen, first in a steel-ball mill and then by hand in an agate mortar. The mills were not asked to make a distinction between the ground clinker and finished cement, for the extent to which these would differ in composition in any particular case through the addition of gypsum to the former was not thought sufficient to have any material effect on the results.

Analyses corresponding to those given in Table I have been made by the Western Precipitation Co.[1] of samples from five of the plants listed in the table. The results obtained are compared with those found in this laboratory in Table IV:

TABLE IV.—*Comparison of results of analyses made by the Western Precipitation Co., and by the Bureau of Soils of raw-mix and cement samples collected on different occasions.*

Company.	Potash in raw mix.		Potash in cement.	
	Bureau of Soils.	Western Precipitation Co.	Bureau of Soils.	Western Precipitation Co.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Olympic Portland Cement Co	0.56	0.42	0.51	0.45
Pacific Portland Cement Co	.50	.52	.50	.43
Santa Cruz Portland Cement Co	.76	.76	.33	.28
Portland Cement Co. of Utah	.94	.92	.24	.21
Security Cement and Lime Co	1.29	1.12	1.05	1.02

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[1] Written communication.

The two sets of analyses shown in this table were made on different samples collected from four months to six months apart. The close agreement in each case affords evidence that at least for these plants the samples collected are representative, and that the potash content of the raw material used in cement manufacture is surprisingly uniform.

Further evidence in support of this conclusion is available. Thus, R. K. Meade, consulting engineer for the Clinchfield Portland Cement Co., reports[1] that he found 2.49 pounds of potash volatilized at this plant per barrel of cement, basing his calculations on the results of analyses of samples secured about a year prior to the time that our samples were obtained. This result differs but 0.03 pound from that given in Table I. Again, of two samples of raw mix which were collected and forwarded to this laboratory nine months apart by the Tidewater Portland Cement Co., both were found to contain 0.71 per cent potash.

It may be pointed out also that as a rule those plants which are situated near one another and apparently use material from the same geological formation show much the same potash content in the raw material used. Thus, there may be compared in this connection the different plants at Bath, Pa.; Nazareth, Pa.; Fenton, Mich.; Mason City, Iowa; Concrete, Wash.; and Hudson, N. Y.

The values listed in Table I for the weights of dry raw mix required per barrel of cement show greater variation than might be expected, and it is possible that some of the values given may depart somewhat from values representing true working conditions. Where no values could be obtained it was assumed that 608 pounds of raw mix would be required per barrel of cement. It is recognized, also, that in individual cases the samples collected may not be representative of normal working conditions, but from the observations made it is thought that in the majority of cases the results given are representative.

ESTIMATED PERCENTAGE OF POTASH IN THE FLUE DUST FROM DIFFERENT PLANTS.

The percentage of potash occurring in the flue dust from any plant will vary (1) with the percentage of potash in the raw material; (2) with the percentage of potash volatilized; and (3) with the amount of dust carried off from the kilns mechanically.

As already pointed out, the quantity of dust collected daily in the flue stacks and treaters of the plant of the Security Cement and Lime Co. amounts to about 61,000 pounds. If it be assumed that this represents a recovery of 95 per cent of the total dust, then the total dust escaping from the kilns of this plant amounts to about 4 per cent of the charge fed into the kilns. If it be assumed that the dust thus collected has undergone about 50 per cent calcination, then the true loss of raw mix in the form of dust will amount to 5 per cent, which is recognized to be a fair average for the plants of this country using the dry process. In calculating the values given in the last column of Table I, the dust lost from the kilns in plants using this process was accordingly taken as 4 per cent.

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[1] Written communication.

On this basis of a 4 per cent loss as dust, the potash contained in the dust from the Security plant should amount to 10.9 per cent. It happens, however, that 27 per cent of the dust, containing about 4.5 per cent of potash, is collected in the flue stacks which connect the kilns with the treaters, and, therefore, the remaining dust, assuming a 90 per cent precipitation of the potash, should contain 11.1 per cent of potash. A sample of this dust analyzed in this laboratory was found to contain 11.4 per cent of potash.

The quantity of dust lost from plants using the wet process is dependent on a number of factors, such as the dimensions of the kiln, the amount of water in the slurry, and the plasticity of the raw mix. Estimates which have been given the writers vary between rather wide limits. On the basis of the most reliable information obtained, it is probable that a loss as dust amounting to 2 per cent of the raw mix is a fair average. This value was therefore used in estimating the percentage of potash in the dust from wet-process plants. The actual potash content of the dust escaping from any plant will be greater or less than the values given according as the true percentage of dust lost is less or greater than the value cited.

As shown in experiments which are to be described in detail in a subsequent publication, the usual constituents of the water extract of freshly collected flue dust are sulphates, chlorides, sulphides, and polysulphides of potash, soda, and lime. Chlorides occur only in small amounts. The percentage of sulphides and polysulphides in the dust from different plants may vary greatly, and in some cases they may be entirely absent. Free lime is found in all cement dust, and in the water extract of all samples analyzed the basic radicals were found to be in excess. It follows, therefore, that the potash in the water extract of freshly collected flue dust will be present to a greater or less extent in the form of the hydroxide. As the dust becomes carbonated either by chemical treatment or by exposure to the air, the hydroxides present will change into carbonates, and the water-soluble potash then will be obtained principally in the form of the sulphate, which is the form universally recognized as of most value for use as a fertilizer.

The flue dust as collected by electrical precipitation may be (1) used directly as a source of cement material; (2) disposed of as collected for use as a fertilizer or in fertilizer manufacture; or (3) leached with a view to preparing concentrated potash salts. The value of the dust as a source of cement material is estimated usually at about 75 cents per ton. The value of potash in the form of sulphate depends on the concentration and varies at normal wholesale prices from about 70 cents per unit for low-grade material to about 90 cents per unit in material containing a minimum of 48 per cent potassium sulphate, or to 95 cents in material containing a minimum of 90 per cent potassium sulphate. Thus it is seen that a comparatively low percentage of potash in flue dust is sufficient to give it more value as a source of potash than as cement material. By separating and concentrating the potash occurring in flue dust the price thereof per unit is increased, the cost of transportation is reduced, the residue becomes available for cement manufacture, and if the process of separation involves some such treatment as steaming under pressure, the percentage of available potash in the dust of some plants at least may be increased considerably. Against these advantages incident to the separation of the dust must be balanced the relative cost of the operation, which will be dependent on the percentage of potash in the dust. The best method of disposing of the dust is thus dependent on a number of factors which will vary with conditions, and it thus happens that all of the three procedures referred to for utilizing the dust are now being given practical application in plants where the dust is being collected by electrical precipitation.

The work so far done on the recovery of potash from cement plants apparently has been limited to plants using the dry process. No installation for the electrical recovery of the dust has yet been made in plants using the wet process, but it is probable that the electrical method would prove just as applicable to plants of this kind as to those using the dry process. At the temperature at which the gases leave the kilns no precipitation of water would take place, and as long as the temperature of the gases is maintained above 100° while passing through the treater pipes little condensation of moisture should occur. The dust in all probability would be precipitated either in a dry state or as a mud or slurry. If precipitated in the form of a slurry, no electrode hammering system would then be necessary, for the precipitated material would flow down the pipes continuously and a concentrated solution of salts would thus be obtained directly without the necessity of any special treatment.

RATIO OF POTASH TO SODA IN CEMENT DUST.

The extent to which the potash salts in flue dust may be concentrated conveniently is dependent in a large measure on the proportion of sodium salts also present in the dust. It was, therefore, thought advisable to determine the proportion to be expected for a number of plants with a view to gaining some idea as to the quantity of soda that might be contained in the dust. The results are given in Table V.

TABLE V.—*Comparison of the amounts of potash and soda lost in cement manufacture.*

Company.	Plant.	Raw mix.		Cement.		Loss from kilns.		Ratio of percentage losses.	Loss per barrel of cement.		Ratio of potash to soda in flue dust.
		Potash.	Soda.	Potash.	Soda.	Potash.	Soda.		Potash.	Soda.	
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*		*Lbs.*	*Lbs.*	
Alpha Portland Cement Co.	Martin's Creek	0.92	0.48	0.77	0.50	49.1	36.7	1.34	2.82	1.10	2.56
Clinchfield Portland Cement Co.	....	.77	.39	.63	.48	50.6	25.8	1.96	2.46	.63	3.90
Cowell Portland Cement Co.	....	.59	.43	.55	.49	41.7	28.8	1.45	1.50	.75	2.00
Edison Portland Cement Co.	....	.69	.59	.70	.49	39.8	50.7	.78	1.76	1.91	.92
Giant Portland Cement Co.	Egypt	.77	.52	.59	.57	54.5	34.9	1.56	2.69	1.16	2.32
Iola Portland Cement Co.	....	.58	.54	.60	.61	39.2	33.6	1.17	1.47	1.17	1.26
Knickerbocker Portland Cement Co.	....	.81	.50	.78	.59	38.3	24.4	1.57	1.84	.72	2.56
Lawrence Portland Cement Co.	....	1.01	.53	.88	.55	45.7	35.4	1.29	2.82	1.14	2.47
Lehigh Portland Cement Co.	Fogelsville....	.71	.45	.47	.38	58.6	47.2	1.24	2.53	1.29	1.96
Do................	Mitchell.......	.79	.61	.71	.71	43.8	27.2	1.61	2.11	1.01	2.09
Do................	Ormrod.......	.63	.39	.38	.52	62.2	16.4	3.80	2.37	.39	6.07
Do................	Mason City....	1.00	.50	.63	.61	61.5	25.5	2.41	3.82	.79	4.84
Marquette Portland Cement Co.	....	.70	.58	.63	.66	44.4	29.7	1.49	1.91	1.06	1.80
Nazareth Cement Co...	....	.84	.61	.64	.60	53.3	39.7	1.34	2.78	1.50	1.85
Northwestern States Portland Cement Co.	....	1.08	.43	.99	.44	41.9	38.3	1.09	2.72	1.04	2.62
Pacific Portland Cement Co.	....	.50	.71	.50	.98	35.0	10.3	3.40	1.03	.43	2.40
Portland Cement Co. of Utah.	....	.94	.70	.24	.65	84.9	45.2	1.88	5.14	2.04	2.52
Texas Portland Cement Co.	....	.90	.37	.81	.45	43.9	24.2	1.81	2.41	.55	4.38
Vulcanite Portland Cement Co.	....	.58	.36	.58	.41	40.6	32.4	1.25	1.51	.75	2.06
Whitehall Portland Cement Co.	....	.77	.58	.58	.66	50.6	25.4	1.99	2.26	.85	2.66

Table V shows that for those cases examined the percentage of potash in the raw mix with one exception is in excess of the percentage of soda. With one exception, also, the percentages of potash volatilized are considerably in excess of the corresponding values found for soda. It consequently happens that the calculated excess of potash over soda in the dust is in most cases quite marked, the ratio of potash to soda varying in the case of the samples examined from 0.92 to 6.07, with an average of 2.66.

POTASH-PRODUCING PLANTS IN THE UNITED STATES.

The recovery of the potash which escapes from the stacks of cement kilns was first made at the plant of the Riverside Portland Cement Co., using the Cottrell process of electrical precipitation. The first unit of this installation was completed in 1912, and has been in continuous operation ever since. The following year the installation was enlarged to take care of the gases from 10 kilns, which comprised all the kilns in the plant at that time. This main installation is built on the plate and wire principle,[1] wherein flat plates take the place of the pipes used in later installations as collecting electrodes and the gases flow horizontally between the plates instead of vertically as is the case where pipes are used. Two kilns were later added to the equipment of the original plant, and to take care of the gases from these kilns the multiple-pipe system was installed.

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[1] Schmidt, W. A., loc. cit.; U. S. Patent No. 1,200,887.

In the case of the plate and wire treater a separation of the dust according to the size of the particles is in a measure effected during the process of precipitation, and it thus happens that the fineness of the dust collected and the percentage of potash present in the precipitated dust increase with the distance of the collecting hoppers from the kilns. In the multiple-pipe treater, however, no separation of the dust takes place other than that brought about by deposition of dust in the flues connecting the treater with the kilns. This dust is coarser and contains a lower percentage of potash than the average of that precipitated.

In the original method used for taking care of the material precipitated at this plant all of the collected dust was burned in one of the kilns connected with the multiple-pipe treater, and the dust there precipitated separately collected. The dust thus recovered on second precipitation showed a marked concentration of potash, which sometimes ran as high as 20 to 23 per cent. This process of concentrating the potash was abandoned later, as it was found that the potassium sulphate in the treater dust was less readily volatilized than the potash in the original mix, and although a high-grade potash material could be obtained in this way the double treatment actually resulted in a loss of potash, due to the comparatively greater percentage contained in the final clinker.

In the method now followed for disposing of the collected material the coarse dust which settles in the long connecting flue of the multiple-pipe treater and in the two rows of hoppers nearest the kilns in the plate and wire treater is returned to the kilns for use as cement material. The dust precipitated in the multiple-pipe treater and in the two remaining rows of the plate and wire treater is separately collected and is either disposed of directly for use as a fertilizer or leached with water at a temperature above 85° for the preparation of concentrated potash salts.[1] By the use of feldspar the potash in the raw mix at this plant has recently been increased considerably above the value given in Table I, with corresponding gains in the quantity of potash volatilized and recovered.

In the plant of the Security Cement and Lime Co. the multiple-pipe system alone is used. In this installation the original flue stacks are still retained, and each serves as part of the connecting flue which conducts the gases from the corresponding kiln or kilns to the treater with which it is connected. By this indirect method of connecting the kilns with the precipitating system the gases before entering the treaters are cooled by radiation in the flues to the desired temperature for the precipitation of the dust.

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[1] Huber, F. W., and Reath, F. F., U. S. Patent No. 1,220,989.

Several precipitating installations are also in operation at plants controlled by the Universal Portland Cement Co., but as indicated in Table I the dust from these plants is too low grade to be of value as a source of potash. The dust collected in the treaters at these plants, therefore, is returned to the kilns automatically, for use as cement material.

In the precipitating system recently installed at the Cementon plant of the Alpha Portland Cement Co., the gases from the kilns are passed successively through a boiler and economizer system before entering the treaters. In this way the waste heat of the gases is utilized for the generation of power by steam turbines. In this installation, as well as in the multiple-pipe treaters already referred to, an artificial draft produced by a fan placed beyond the treater system replaces the natural draft originally given by the flue stacks.

The advantages claimed for installations of the kind last mentioned are as follows: (1) The abatement of the dust nuisance is effectively secured; (2) material is recovered suitable as a source of potash or cement material or of both when separation of the potash is brought about; (3) a greater efficiency in the burning of the cement is secured owing to better possible regulation of the draft through the kilns, with resultant economy in the amount of fuel required; and (4) utilization of the waste heat of the gases from the kilns.

In the plant of the California Portland Cement Co. use is made of the Fleming patent dust-collecting system.[1] This system has been in operation since 1912, and it is claimed that this method of collecting the dust is not only efficient but it is also more than self-supporting, there being a saving to the company in the dust collected, a larger output per barrel of oil used for fuel, and fewer shutdowns than before the Fleming system was installed.

The draft for the kilns is produced by fans sucking at the end of separate flues. Instead of discharging the gases into the atmosphere, these fans blow the dust and fumes into a large dry dust-settling chamber, where the velocity of the gases is reduced 90 to 95 per cent and about two-thirds of the dust is deposited. The gases carrying the extremely fine dust which does not settle then go to wet washing chambers, where they are forced up and down several times through a system of seven baffle sections in each of which are sprays of water for capturing the remaining dust. In both the wet and dry chambers means are provided for removing the collected dust to the cement kilns. The same water being repeatedly used in the wet baffle chambers, it soon becomes charged with soluble salts, principally in the form of sulphur compounds of potassium, sodium, and calcium. When more than one-half pound per cubic foot is found some of the solution is removed and replaced by fresh water in order not to cause trouble with the sprays. Steps are now taken to recover the potash, but further details of the operation are held confidential.

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[1] Hanna, W. C., Metallurgical and Chemical Engineering **13**, 609 (1915).

Extensive experiments on a wet process for the recovery of potash in cement dust have also been made at the plant of the Sandusky Cement Co. One method of procedure as outlined in a patent[1] granted to the president of this company has for its object the recovery of the water-soluble potash in the dust. This is done (1) by causing the gases to pass over water contained in shallow vessels in which the solution of alkali salt is produced and replaced as it becomes saturated, or (2) by causing the gases to pass upward through a tower filled with an open checkerwork of brick at the top of which a spray of water is introduced. The flue is so adjusted that most of the water is evaporated in its descent over the extensive brickwork surface in contact with the gases and a small stream only of a concentrated salt solution is discharged continually at the bottom of the tower.

In a process described in the specifications of a subsequent patent[2] provision is also made for the recovery of the insoluble potash in the dust and for utilizing the waste heat of the gases. This is done by passing the gases first through suitable dust chambers and then successively through a boiler and economizer system before passing into the spray system as outlined in the preceding patent. The dust which is deposited in the connecting flues of the system and the mud which settles out from the concentrated salt solutions are then returned to the kilns for the purpose of volatilizing the potash present with a view to its ultimate recovery in soluble form. The experiments on the commercial application of the methods outlined in these patents have not yet been completed. It seems doubtful, however, from observations made in various industries on the use of spray washers for the purification of gases from a suspended fume, whether any wet process will prove as effective as the electrical process for the recovery of potash from cement flue dust.

The recovery of potash from feldspar by use of the latter in the manufacture of cement has recently been investigated on a commercial scale by the Buffalo Potash & Cement Corporation, operating under the Brown[3] and Warren[4] patents.

In the process outlined in these patents feldspar is ignited in an oxidizing atmosphere with a sufficient quantity of calcium chloride to furnish sufficient chlorine to combine with the potassium in the feldspar and with a sufficient quantity of calcium carbonate to bring the lime content of the resulting material up to 40 to 55 per cent. The charge is burned in a modified type of copper blast furnace at a temperature practically the same as that required in Portland-cement practice with rotary kilns. Under the conditions of the operation the charge is reduced to a molten mass yielding a cement containing no free lime and at the same time a high percentage volatilization of the potash is obtained. A combined dry and wet system was first used for recovering the potash, but, not proving satisfactory, this has been replaced by the Cottrell process of electrical precipitation.

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[1] Newberry, S. B., U. S. Patent No. 1,121,532.

[2] Newberry, S. B., U. S. Patent No. 1,150,295.

[3] U. S. Patents Nos. 1,123,841 and 1,124,238.

[4] U. S. Patent No. 1,123,964.

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We wish to express our thanks to the different cement companies listed in Table I for the samples they have furnished us, and particularly to the officials of the Security Cement and Lime Co., the Western Precipitation Co., Mr. R. K. Meade, and others, for the information they have given us.

SUMMARY.

(1) Analysis of samples of raw mix and of cement from 113 cement mills in the United States and Canada shows that the potash in the raw mix varies from 0.20 to 1.16 per cent, and that the percentage of potash volatilized in the different plants varies from 24.5 to 95.9 per cent. From the results thus obtained it has been calculated that the potash escaping from the kilns of these plants ranges from 0.35 to 5.14 pounds per barrel of cement produced, with an average for the plants of this country of 1.93 pounds. On the basis of an average production of 90,000,000 barrels, the total potash escaping from the cement plants of this country amounts to about 87,000 tons annually. It has been demonstrated commercially that 90 per cent of the potash escaping in the dust is recoverable, and from experiments made in this laboratory it would appear that 95 per cent of the recoverable potash is, or may readily be made, available. The recoverable potash in the cement industry therefore amounts to approximately 78,000 tons and the available recoverable potash to 75,000 tons, or to 71,000 tons when plants losing less than 1 pound of potash per barrel of cement are omitted.

(2) Assuming, in the light of results that have already been obtained, that it would be practicable to increase the percentage of potash volatilized to at least 65 per cent for all plants, then the available recoverable potash would amount to more than 100,000 tons annually, or to nearly one-half of the normal consumption of potash in this country.

(3) If it be assumed, further, that the dust escaping from the kilns amounts on an average to 4 per cent of the raw mix fed into the kilns in the case of dry-process plants, and to 2 per cent for plants using the wet process, then, on the basis of the results already given, the total potash content of the dust escaping from the former plants will vary in different plants from 1.4 to 20.0 per cent, and in the latter from 9.1 to 35.1 per cent.

(4) The ratio of potash to soda in the dust as determined for 20 different plants varies from 0.92 to 6.07, with an average of 2.66.

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